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## Hands on Design : Comparing the use of sketching and gesturing in collaborative designing

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## Hands on Design: Comparing the use of sketching and gesturing in collaborative designing

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**Abstract:** This study explored the remaining potential of gestures as creative tools for collaborative designing. We compared novice designers' use of sketching against gesturing in early ideation and rough visualisation. To preserve the kinesic character of gestures, we developed a detailed video analysis method, which revealed that majority of sketching and gesturing were complementary to speech. Sketching was important for defining complicated structures, while gesturing was frequently used for all aspects of designing. Moreover, we identified that the level of collaboration—the level and immediacy of sharing one's ideas for others—is an important factor. As an underrepresented phenomenon in the design literature, the meaning of collaboration unearthed here leads to unmistakable conclusions regarding the nature of gesturing, to the process of learning design, and to the use of design tools. Most notably, gesturing offers a complementary creative dimension—kinaesthetic thinking—which invites us to communicate and share instantaneously.

**Keywords:** *collaborative design; design communication; design ideation; design learning; gesture; gesturing; gestural concepts; sketching; video analysis; micro analysis; kinaesthetic thinking; visualisation*

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**Biographical notes:**

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## 1. Introduction

In many respects, gesturing and sketching cannot be evenly compared. They each allow for different levels of idea sharing: sketches are often finalised before sharing, while gestures cannot be saved for later but rather reveal ideas immediately, providing a foundation on which others can build. Sketching is a celebrated design skill: a tool for thinking and communication (Lawson, 1997; Schön, 1983) that is regularly introduced to design students. Gesturing is a spontaneous communicative behaviour that is typical to some but not all (Chu et al., 2014). It is rarely studied in design, even more rarely in design education, and it is unlikely to be included in a design curriculum (Cash and Maier, 2016), despite testimonies regarding the importance of gestures in design (Bekker et al., 1995; Tang, 1991; Visser, 2010; Visser and Maher, 2011). In mathematics education, gestures have been studied for twenty years, with the results suggesting that encouraging students to gesture may activate their implicit ideas and even invoke new ideas (Goldin-Meadow, 2014). Therefore, this study explores the remaining potential of hand gestures as tools for designing artefacts—as tools for collaborative thinking and communication by comparing the use of gesturing to the use of sketching in the early phases of collaborative designing, from conceptual ideation through rough visualisation.

### 1.1. Roles given to gestures

In the field of design, the value of gestures and multimodal communication were recognised along with the development of computer systems for distributed collaborative design. Design research regarding gestures surged in the 1980s and 1990s, and gestures were identified as *an important communication medium* that expresses information not expressed by speech, provides information that demonstrates spatial content and actions and encourages focused and organised attention (e.g. Bekker et al., 1995; Tang, 1991). Ever since, implications regarding human-computer interfaces have been the major motivator for design research concerning gestures. Yet, empirical research designed to

systematically build understanding of the value of gestures in face-to-face design has been scarce (Visser and Maher, 2011).

In gesture studies, the role of gestures was broadened from the idea of communication to include *revealing thoughts* (McNeill, 1992) and further to include *fuelling thoughts* (McNeill, 2005). Resonating with these ideas, Visser (2009) and Murphy (2005, 2012) declared gestures to be dynamic *carriers of design ideas* that help create and shape those ideas. Eris et al. (2014) further introduced the theory of gestures as *a kinaesthetic thinking medium* that reduces cognitive load, supports the creation of tactile experiences and allows the enactment of scenarios. However, empirical design research from this latter viewpoint is limited.

In gesture studies, several micro-level analyses have revealed that in spatial dialogue 50% of gestures convey complementary meanings in relation to speech (Bergmann and Kopp, 2006). Furthermore, *the importance of gestures for spatial cognition*—in expressing, communicating and thinking about spatial information—has been widely acknowledged (cf. review by Alibali, 2005). Although some people gesture substantially more than others (Chu et al., 2014), gesturing also appears to be task dependent. Spatial task content doubles the number of gestures used (Lavergne and Kimura, 1987). Furthermore, active thinking, reasoning and arguing—common to collaborative designing—increase gesturing as compared with describing something that is well known (Clark, 2008). These points suggest that gestures are also important *for* designing and not only *in* designing.

Many researchers agree that using gestures along with speech yields better understanding and knowledge transfer (Goldin-Meadow and Beilock, 2010; Kendon, 2004; McNeill, 1992); however, all underlying mechanisms are not clear. Streeck (2008) challenges the idea of gesturing as transforming an experience into a *purely visual representation* and offers an alternative explanation: *haptic epistemology*. He sees gestures as organising the world fundamentally differently than words allow—presenting the world as ‘hand-able’ rather than visible or speakable (Streeck, 2009). An example of haptic epistemology is *ceiving*: conceiving or making sense through gestures, where gestures take on the role of *conceptual actions* (Streeck, 2009).

## *1.2. Sketching and gesturing in design research*

Design research has recognised that both sketching (Lawson, 1997; Schön, 1983) and gesturing (Bekker et al., 1995; Tang, 1991; Visser and Maher, 2011) provide essential information that is lacking in speech. In sketching, this complementary information is oriented towards developing the solution, while gestures help develop the solution and organise collaboration (Eris et al., 2014; Tang, 1991; Visser and Maher, 2011). The following section compares sketching and gesturing via empirical design research.

Characteristically, sketches and gestures are quite different. Sketched marks-on-paper provide a memory aid that can be archived for later use (Goel, 1995). Gestures, which are temporary, need to be capitalised on instantaneously; however, participants might remember gestures even in later meetings (Tang, 1991). Gestures are four-dimensional and dynamic: action and movement in time or space appear naturally as they render virtual objects and action-scenes. Conversely, sketches are principally static in 2D. Yet, both sketching and gesturing are simplified abstractions that concentrate on features considered essential to a current task (Streeck, 2009; Tversky, 2002). *They direct designers' and their co-designers' attention towards relevant features of the idea.*

As focused representations, sketches and gestures guide designers to comprehend, evaluate and build on the presented ideas. Their ambiguousness allows reinterpretation, which has both intentional and unintentional consequences (Schön, 1983). Similar to the explorative cycles of sketching (representing), reinterpretation and evaluation are central to the production of design ideas (Goldschmidt, 1991; Schön, 1983). Those explorative cycles of representing and reinterpretation can rely solely on one expressive modality, such as sketching. In collaborative settings, different modalities—speech, sketching, gesturing or material modelling—are often used for reinterpretation, which allows the characteristics of the modalities to further shape and enrich each reinterpretation (Murphy, 2012). In sum, *sketching and gesturing together provide both more and varied possibilities for enriching design ideas.*

Sketching is recognised as visual thinking and reasoning (Goldschmidt, 1991; Oxman, 1997), and gesturing has a meaningful role in spatial cognition (Visser and Maher, 2011). Spatiality and time-dimension of gesturing support simulations, such as end-user behaviour (e.g. Bekker et al., 1995; Eris et al., 2014; Tang, 1991) and relative movement of the

artefact's parts (Cash and Maier, 2016). *Sketches and gestures ease the manipulation of visual and spatio-temporal forms of information.* However, in Hummels' (2000) experiments of gesture-based design tools, although most of the participants welcomed the idea, essential differences existed in preferences, use of gestures and levels of detail in the participants' designs.

When both sketching and gesturing in designing have been studied, their roles have varied. Some findings can be generalised for collaborative work, such as gesture sequences used for walkthroughs, listing, contrasting and emphasising (Bekker et al., 1995), and replicating gestures to signal different levels of approval or modification of an idea (Cash and Maier, 2016). Others have emphasised features specific to design activity or designers. Eris et al. (2014) suggested that the roles were dependent on the design process phase: gesturing was favoured for exploring the problems and generating concepts, and sketching was favoured for detailing a concept once it had been identified. By contrast, Adler et al. (2004) recognised that some designers preferred gesturing while others sketching, with some sketching regularly to substitute gestures. The tendency to sketch and gesture for the same purposes was also recognised by Detienne and Visser (2006). Further, Murphy (2005) found that architects used gestures to 'add' new buildings to drawings, treating them similarly to the sketched ones. That behaviour was not restricted to the creators but also applied to other participants in the meetings; gestures became permanent marks, virtual objects. In turn, Visser (2009) concluded that no fixed functions could be connected to gesture forms. In sum, *the roles of sketching and gesturing as tools for designing are not fixed.*

Suitability of a tool is not only about the features of the tool but how the tool is used. Building an understanding of tool suitability is one task of design education. Novice designers might be reluctant to sketch (Authors, 2014; Booth et al., 2015), and gestures support spatial thinking (Visser and Maher, 2011) as well as reflective dynamic simulations (Cash and Maier, 2016) and idea generation (Goldin-Meadow, 2014). The purpose of the present study is to *explore the remaining potential of gestures as tools for collaborative thinking and communicating in the early phases of designing, where conceptual ideas are generated, evaluated and negotiated.* To meet that objective, we compared the roles of sketching and gesturing. Our research, in the context of novices designing material

artefacts in the absence of props other than pen and paper, addresses the following questions:

- (1) To what extent do sketching and gesturing complement accompanying speech?
- (2) What aspects of designing do sketching and gesturing complement?
- (3) Are there differences in how sketching and gesturing are used for different design tasks?

Following an overview of both the research setting and the analysis method, we report the results and conclude with a discussion.

## **2. Method**

The present study belongs to research project XX involved with novice designers' challenges and developing educational practices for collaborative design. The project has employed several methodological approaches with differing levels of granularity (cf. Cash, Hicks & Culley, 2015). The pedagogical settings were scrutinized in Authors (2017). Macro-level video analysis of the entire design process supplemented with a meso-level descriptive analysis of design approaches, was conducted in Authors (2016a). Authors (2016b) zoomed into meso- and micro-level details of collaborative sketching. For each publication, previous analyses revealed new avenues, which were then scrutinised. That path brought us to the present micro-level study of the potentials of gestures as tools for creative ideation.

### *2.1. Setting*

For research project XX, teams of three first-year undergraduates received authentic design and make assignments, which were part of 'The basics of craft science and design' at the University of XX. The course was compulsory for students studying to be textile teachers (MAEd) who would then be teaching designing in primary and secondary schools. These students are generally novices in designing.

A collaborative design and make assignment—a 3D textile puzzle for visually impaired children aged 3–6 years—was given to students via a written design brief. It stated that the puzzle pieces were to be larger,

thicker and more durable than normally, that the puzzle needed to comprise at least three pieces and that the teams were to finalise the puzzles by using textiles and sewing techniques. The assignment represented a real-world design challenge with real-world clients: visually impaired children. These children were represented by Celia, a library for all print-disabled people ([www.celia.fi](http://www.celia.fi)). The students were provided with inspirational sources (a Celia-produced guidebook for tactile book making) as well as further external constraints (a timed schedule and a low budget). The assignment was pre-structured to three design sessions—identifying design constraints; visualisation by sketching; 3D modelling—with specific tasks, followed by making. Before the visualisation session, the students individually solved a creative problem-solving task (adapted from Sawyer, 2013, p. 33), which guided them to use certain forms in the collaborative design task. This setting was aimed at encouraging students to explore several design ideas and to stretch their creativity while supporting novice designers' first design assignment at the university.

## *2.2. Data collection for research project XX*

From 36 course participants, we selected 12 students based on their willingness and participation in a simultaneous sewing technology course, where the designs were completed. The selected students, aged 20–48 years, were assigned to four teams of three based on their curriculum choices and answers to questions regarding their sketching habits. We video-recorded the teams' sessions with one top-view and one side-view camera and collected all produced documents. During the sessions, no additional props or artefacts other than pens and paper were provided (Figure 1). Two weeks after the last design session but before the making, we video-recorded stimulated recall team interviews.

<Figure 1>

**Figure 1** Working environment, top-view camera



### 2.3. Data selection

Professional designers highly skilled in sketching are studied to deepen the field's understanding of sketching as a tool. Likewise, a study of novices 'skilled' in gesturing could build understanding of gestures as tools for novice designers or designers less proficient in sketching—an assumption we used as a data selection criterion. Further, a study of *efficient collaboration—collaboration that maximises the level of shared idea development*—could broaden our understanding of gestures and sketching as generative design tools. In cases where sketching results in an attenuated use of interpersonal working space (Peter et al., 2013), thus, a limited sharing of ideas (van der Lugt, 2005), the benefits from collaboration remain shallow. However, our interests lie in developing tools for collaborative idea generation, especially tools suitable for novice designers.

In our previous study on sketching (Authors, 2016b), based on an analysis of the above-mentioned teams, we identified four different ways to sketch in collaborative setting. The key difference was the level of collaboration, especially sharing of the sketched content: micro-level analysis revealed considerable differences between the use of collectively shared and private working spaces as well as in the time it took for the sketches to be shared. As mentioned previously, substantial differences between people exist in the frequency and saliency of their gestures (Chu et al. 2014). Indeed, some of our teams used almost no gestures or chiefly pointing gestures. Team Landscape used both rich and varied gestures as well as immediately shared sketching to develop their design; thus, an interesting path to explore would be the richness of gestures to further understand the dimensions of generativity, both for sketching and gesturing. Regarding their sketching habits, the team members reported no aversions to sketching. They had a shared interest in sewing—a shared technical and experiential background central to the design and make tasks. Additionally, their experiences with visually impaired people were quite limited. Therefore, we selected Team Landscape for this study.

The data selected comprised two (45-minute) sessions: 'Defining Design Constraints (DCC) and Visualisation by Sketching (VbS). The sessions were video-recorded by two cameras, one hanging from the ceiling and one mounted on a tripod, which produced three hours of video and 9 documents. Team Landscape's interview comprised 90 minutes of video. Figures 2a and 2b summarise the structure of the assignment and

the products created. The present study focuses on the design sessions that appear in Figure 2a.

<Figure 2a>

**Figure 2a** The functional 3D puzzle: tasks for the first two design sessions and the products by Team Landscape

<Figure 2b>

**Figure 2b** The functional 3D puzzle: tasks for the third design session and make phase, as well as the products by Team Landscape

#### *2.4. Data analysis method*

For this micro-level analysis, we designed five analytical steps (Figure 3). First, we segmented the videos into sketching and gesturing events (Step 1). For each event, we interpreted the meanings conveyed by either sketching or gesturing and determined if those meanings were complementary in relation to speech (Step 2). We continued by identifying the aspects of designing, where sketching and gesturing complemented speech (Step 3). Next, we compared the use of sketching and gesturing at the level of the pre-defined pedagogical structures (the design sessions) (Step 4) as well as at the level of dynamically unfolding operations with high-intensity groups of consecutive events of the same type (Step 5).

<Figure 3>

**Figure 3** Data analysis steps

To analyse actions often shorter than one second, we chose the INTERACT video analysis program, which supports the observation picture by picture and allows for an unlimited amount of annotations. Annotations were used not only for transcribing speech and describing sketched and gestured content but for documenting the interpretations of

the meanings conveyed by sketching and gesturing. When competing interpretations occurred, the guiding principle was to avoid decisions based solely on verbalised transcripts and to rely on running video footage. Hence, we tried to avoid logocentric interpretations and to save the characteristic features of sketching and gesturing, which increased the validity of the results. The environment, the INTERACT software and our method for carrying out the video analysis appear in Figure 4.

<Figure 4>

**Figure 4** Video analysis with INTERACT. Left: events and classifications; bottom right: video window; top right: timeline chart

#### *2.4.1 Segmenting (Step 1)*

The challenge was to maintain comparability between gesturing and sketching events. In theory, both gesturing and sketching have distinct beginning and end points, hand movements and pen strokes. Kendon (2004) and McNeill (2005) both separate gestures into phases: the gesture starts and ends with the hands in a stable resting position, with the content-bearing part of the gesture—the stroke—in the middle. In our data, gestures often appeared as long sequences (cf. Cash and Maier, 2016), with no rests in between strokes. To compare gesturing and sketching, we treated all gesture strokes as separate events and defined the sketching event per Garner (2001): continuous sketching interrupted by pauses shorter than one second. This segmentation practice and some of the same data were also used in Authors (2016a).

#### *2.4.2 Identifying complementary sketching and gesturing (Step 2)*

Sketching and gesturing complement speech if they convey meanings that are not expressed in the accompanying speech. To analyse the meanings, we utilised a method based on Enfield (2009) presented previously in Authors (2016b). In general, each meaning has two ‘layers’: an apparent

global meaning and a context-based local meaning requiring interpretation. A global meaning could be a geometric shape, such as ‘a triangle’. To understand that a sketched or gestured ‘triangle’ meant ‘a mountain’ in a conversation, we needed the context: speech, previous or subsequent gestures and sketches, head nods and facial expressions. Video analysis software played a crucial role in providing the context and documenting the interpretations: for each event, only accompanying speech was transcribed in full, and the effort was directed towards documenting impressions based on graphic and kinesic features seen on the running video (‘a triangle’, for instance). Those impressions, together with the context, were used to determine how best to interpret the event’s meaning (‘a mountain’, for instance). Luckily, the interpretation of gestures in our data was rather straightforward; they mostly described shapes and real-world objects or the handling of such but not abstract concepts.

Next, we compared the meanings conveyed by each sketching and gesturing event to the accompanying speech. When the meanings were not identical, we classified the event as complementary. This division is elemental to both the rest of the study and drawing any conclusions from our data.

#### *2.4.3 Identifying complemented aspects of designing (Step 3)*

To identify design aspects complemented by sketching and gesturing required two steps. Firstly, we separated events used to organise and regulate the conversation—meta-communicative events—from events that directly contributed to designing a puzzle. Secondly, more detailed classifications of the latter events were required. We developed a data-driven classification (Table 1) that shows the characterising features of Team Landscape’s design: the importance of structure and materiality (classes: Structure, Material quality, Making), the challenges related to an unfamiliar end-user group, visually impaired children (classes: End-user behaviour, Source of inspiration), the simultaneous presence of sketches and gestures (class: Link to object) and the meta-communication necessary for organising a collaborative design.

**Table 1** Classification of design aspects complemented by sketching and gesturing

Category	Explanation	Examples
Structure	Shape; Size; Height; Construction	Round; Parts with various heights comprise a landscape
	Connection between parts	Enacting the opening of a Velcro fastener
Material quality	Texture; Weight; Flexibility; Visual quality; Contrast	Weighting two fictitious objects: one heavier and one lighter
End-user behaviour	Enacting a behaviour imagined typical to a visually impaired child	Touching to perceive an object Simulating a child placing puzzle pieces in different places
	Enacting the end-user using the product	
Source of inspiration	Enacting a scenario of a source of inspiration based on personal experience	Simulating a child playing with a wooden cube puzzle;
		Simulating a blindfolded child on a path full of textures to probe
Making	Enacting making the product	Simulating a technique: hand sewing, tucking, embroidery
Link to object	Pointing to an object upon sight	Pointing to a sketch
Link to abstract object	Pointing to the location of either an imagined object or a previous gesture or to an abstract object, such as a situation, time or a previous conversational topic	Pointing to a location behind one's back to refer to 'another course';
		In a series of gestures describing 'a flowering cactus in a pot', the opening gesture reserves a space for 'the cactus' so that later gestures in the series can refer to this space
Meta-communication	Regulating either the communication or the design process;	Reserving a conversational turn; Simulating sketching on paper to suggest that a sketch should be placed there

#### *2.4.4 Compiling the session level (Step 4)*

Both sessions—Defining Design Constraints (DDC) and Visualising by Sketching (VbS)—represent conceptual designing, but the latter includes a shift from abstract (language-based) concepts to rough 2D modelling. The task instructions favoured writing in DDC and sketching in VbS; hence, it was clear that sketching would have a larger role in VbS. To understand whether different contexts created by the pre-determined tasks would affect the character and role of gestures, results of steps 1–3 were compiled on the session level.

#### *2.4.5 Compiling the operations level (Step 5)*

To further enhance our understanding of the specific situational characters inviting the team to sketch (or gesture), we identified dynamically unfolding operations that could be particularly suited to sketching (or gesturing). These high-intensity operations comprised either exclusively of consecutive sketching or consecutive gesturing events. The developed qualitative classifications are discussed in the results section.

### *2.3 Reliability*

Systematic analyses comparing explicit interpretations of several listeners (or researchers) on *all* gestures during a spontaneously flowing conversation are rare. To measure our success in developing categorisations, two coders worked independently with text-based instructions only, which yielded a substandard inter-rater reliability (IRR). After the first author had analysed disagreements and updated categorisations, the first and second authors together classified a sample and discussed their disagreements while watching the respective video parts. This grounding to the gestures' kinesic features yielded satisfactory levels of IRR. For an explorative study such as this, we considered 0.73 sufficient for the Design aspects, and the more critical division of Complementary vs. Non-complementary reached 0.9. For sample sizes and Krippendorff's alphas, see Table 2.

**Table 2** Inter-rater reliability per category

Sample size	Category	Krippendorff's alpha
Independent coding based on text-based instructions		
97	Complementary vs. non-complementary	0.74
Coding together while watching the video		
121	Complementary vs. non-complementary	0.9
121	Design aspects	0.73

### 3. Results

This study compared sketching and gesturing as collaborative tools for conceptual designing and rough visualisation with the aim of understanding how novice designers could benefit from gesturing. Because the data represents a team of novice designers ‘skilled’ in gesturing, the results should not be generalised over populations but rather viewed as suggesting avenues for future research, as explicated in the Discussion section.

#### 3.1 *The extent of complementary sketching and gesturing*

*Complementary meanings comprised a clear majority in both sessions.* In DDC (430 events), 100% of sketching and 58% of gestures were complementary (5 sketching and 425 gesturing). In VbS (617 events), 87% of sketching and 64% of gesturing were complementary (100 sketching and 517 gesturing). Due to the granularity level in segmenting, the numbers were high yet comparable: each event produced at least one ‘meaning’ that was shared—a meaning that the team could build on and evaluate.

#### 3.2 *Design aspects complemented by sketching and gesturing*

*Complementary gesturing enriched designing in more versatile ways than sketching.* Sketching was almost without exception used to complement

Structure and Meta-communication, while complementary gestures were dominant in all aspects of designing except Meta-communication and Linking to abstract objects (Table 3). The importance and primacy of gestures in maintaining face-to-face collaboration is reflected in the high frequency of Meta-communication (cf. Stevanovic and Monzoni, 2016).

**Table 3** Complementary gestures dominate most aspects of designing  
Comp=Complementary; Non=Non-complementary meaning

	Defining Design Constraints			Visualisation by Sketching		
	Comp	Non	Totals	Comp	Non	Totals
Structure	55	18	73	71	25	96
Material quality	28	7	35	21	4	25
Source of inspiration	18	6	24	3	1	4
End-user behaviour	33	13	46	22	10	32
Making	5	2	7	15	1	16
Link to an object	29	7	36	138	46	184
Link to an abstract object	14	31	45	8	21	29
Meta-communication	66	93	159	54	77	131
Total frequencies	248	177	425	332	185	517

In general, the high number found in Structure was expected because the team was designing a 3D puzzle; however, it was unexpected to find Structure more frequently complemented by gestures than sketching in DDC as well as in VbS. That was partly due to the team gesturing the same structural ideas several times but sketching each idea only once and partly because gesturing introduced many central ideas. The only structure developed by sketching was the base layout of the puzzle—the most complicated structure. In that development, having the pointing gestures (Link to an object) focused on tiny details of the sketch was vital because



the speech would have otherwise been incomprehensible. The single-use character of gestures, as compared to sketches as permanent marks, affected the frequencies. However, identifying which gestures were unique and which included some ‘finetuning’ was impractical because the ‘repeated’ gestures were seldom identical to the originals. They merely preserved the central features, making them recognisable as ‘the same’.

A central design aspect that was complemented by gestures but not by sketching was End-user behaviour. The team was committed to responding to the needs of visually impaired children by simulating their interactions with the puzzle-to-be and learning, perceiving and knowing via touching. Certain powerful *gestural conceptualisations* were repeated often, such as ‘weighting’ (identifying an object by feeling the weight in one’s hands) and ‘pushing inwards’ (imagining). The following snippets illustrate the team using a gesture to conceptualise how visually impaired children imagine.

### **Imagining as ‘pushing inwards’**

The team discussed the puzzle being used when telling stories and how different pieces could offer tactual experiences to stimulate imagination.

<Figure 5>

**Figure 5** Grace (left) gesturing to Bessie (middle) and Rose (right) as to how visually impaired children imagine

Grace’s hands were on both sides of her head, with her fingers adducted and her palms facing back. She flapped her palms rapidly backwards and forwards—as if pushing inside—and said: ‘In principle, a visually impaired child, when you’re telling a story to her, she always imagines it’ *DDC*, 27:49.

It is hard to see this gesture *as a visualization* of imagining, which is an activity within the mind. This gesture moves something from the outside to the inside of the head. *The gesture conceptualises the activity of imagining differently than the words do.*

Less than one minute later, Bessie repeated this gesture with a slight modification: with her right hand in front of her face and fingers adducted, she pushed rapidly towards her head twice with her palm. She was speaking about hearing, but the gesture referred to imagining:

‘It would make the story she hears, in a way, more concrete’ *DDC*, 28:15.

Repeating gestures (produced by previous speakers) signal shared conceptual foundation (cf. a review by Chui, 2014). The simplification of hand movements denotes a general tendency to settle with more referential expressions as the conversation continues (Schober & Clark, 1989). Ten minutes later, Bessie simplified her gesture further. Her speech and gesture both referred to imagining:

‘She can create a fantasy world—a product of her imagination’  
*DDC*, 38:24.

The following two snippets show how this gesture was adopted to also refer to children with normal eyesight.

Bessie raised both hands towards her temple, with her fingers slightly spread apart, and made a couple of quick pushes. Her speech was about a child who starts to play; however, the gesture referred to imagining:

‘He immediately starts to play’ *DDC*, 38:16.

Bessie, with her right hand raised, pushed twice towards her temple. Her speech and gesture both referred to imagining:

‘[The child] completes it [the puzzle] as she has created it in her imagination’ *DDC*, 38:43.

These snippets show that, as the team mimicked the gesture, *the meaning related to certain kinesic features became shared knowledge* (see LeBaron and Streeck, 2000)—a gestural concept (Streeck, 2009) that was a part of the team’s shared ‘conceptual lexicon’.

### *3.3 Use of sketching and gesturing in design sessions*

We compared sketching and gesturing in two design sessions: conceptually-oriented defining of design constraints (DDC) and spatially-oriented rough visualisation of a 3D puzzle (VbS). Both sketching and gesturing were more frequent in VbS because the task called for sketching, which invited pointing gestures. Within the design phases, gesturing was more frequent in the later phase yet less versatile than in the beginning. In DDC, the team thoroughly analysed Material qualities and End-user behaviour as well as introduced several Sources of inspiration. In VbS, they emphasised the details of both Structure and Making.

### *3.4 Use of sketching and gesturing for operations*

We further identified four emergent types of operations (Table 4), where either sketching or gesturing dominated. We assumed that dominance implied that certain features had invited the favouring of one modality. Interestingly, only one operation favoured sketching: defining the puzzle base structure (operation 1). In this complicated effort, the selected geometric forms were used to create puzzle pieces with two horizontal layers: a base with tight-fitting forms, which could be assembled in various ways, and a top representing various landscape elements, such as trees, mountains or a river. Fitting the base-layer forms together required a stable representation—a memory aid—via a sketch that was collaboratively evaluated, modified and re-drawn several times.

Three other operations favoured gesturing. Regarding Ideation based on visible sources of inspiration (operation 2), reference points for ideas already existed as a visual of geometric forms, which were part of the task instructions. For this type of operation, the team used gestures to communicate their ideas, such as ‘two mountains of different heights’. In Understanding end-user behaviour (operation 3), they used the kinaesthetic approach to understand visually impaired children’s thinking, perceiving and knowing by touching, which yielded gestural conceptualisations, such as the previously mentioned ‘seeing inwards’ and ‘weighting’. By contrast, Demonstrating a way to make the puzzle (operation 4) was based on obvious prior knowledge: kinaesthetics, tactile

and material understanding of handling textile materials, sewing and creating textile structures.

**Table 4** Use of sketching and gesturing for operations

No	Operation	Favouring	Explanation
1	Puzzle base-structure: fitting forms together	Sketching	Designing the base structure: two forms fitting tightly together to facilitate multiple ways of organising the puzzle pieces
2	Ideation based on visible sources of inspiration	Gesturing	Generating ideas (especially landscape elements, such as mountains and a river), based on a source of inspiration visible to all, such as selection of geometric forms
3	Understanding end-user behaviour	Gesturing	Simulating and comprehending how visually impaired children behave, perceive and recognise things: perception by touch
4	Demonstrating a way to make the puzzle	Gesturing	Simulating a familiar technique that represents an embodied experience

Lastly, this section illustrates a puzzle-making technique (operation 4). The team members re-presented their embodied experiences in sewing and dressmaking as they demonstrated how to create whorled branches of a spruce.

### **Tucking fabric to create whorled branches of a spruce**

Bessie suggested creating whorled branches by tucking fabric.

<Figure 6>

**Figure 6** The shape of the branches, which Bessie repeated five times

Bessie made upside-down V-shapes five times as she spoke:  
 ‘Could we make the structure something like . . . do you know, like, sewn from several, several . . . It would be lovely’ *VbS*, 20:30.

Bessie, unable to find a word, used a gesture. Next, she gestured regarding possible end results:

Bessie repeated the upside-down V-shapes, first with her right-hand forefinger, then with both palms and said, ‘Do you know what I mean? We could sew like this . . . and like this . . . and this’ *VbS*, 20:39.

Six minutes later, they discussed possible details. Bessie further developed her idea.

She simulated holding the fabric with both hands and, lifting it to chin-level, continued with two quick upside-down V-shapes, with her fingers in a precision grip, to show how the fabric should be tucked. She said, ‘This should be done like such, like . . .’

Next, she continued with five more V-shapes, which became incrementally wider. She seemed to be tucking fabric upwards as she said: ‘. . . fabric like this, like making tucks’ *VbS*, 25:02–28:55.

Rita joined Bessie’s explanation mid-way through. They spoke simultaneously and gestured regarding how to handle the fabric:

<Figure 7 left>

<Figure 7 right>

**Figure 7** Bessie (left) and Rita (right) gestured simultaneously to demonstrate the tucking

Bessie made an upside-down V-shape and said: ‘. . . or then do something like this’

Rita pushed upwards with her right hand and said: ‘like use gathering to . . .’

Rita pushed vigorously upwards four times and said: ‘like . . .’

Bessie continued to demonstrate the tucks:

<Figure 8 left>

<Figure 8 right>

**Figure 8** Bessie first showed one branch, then how the edges of the branches should look (left) and next emphasised the layered structure (right)

Bessie first showed the larger shape of one branch, then how the edges of the layers should look and said: ‘always like such, like sew an edge like this . . .’

She emphasised that there should be several folded layers by repeating the upside-down V-shape six times as she said: ‘then fold it like this’

<Figure 9 left>

<Figure 9 right>

**Figure 9** Bessie simulated how to move the fabric (left) and showed the resulting structure (right)

Bessie continued and simulated the proper grip, followed by the movements needed to tuck one layer underneath the other and said: ‘. . . and then new underneath it, so that it, you know’

Then, she ended her sentence by saying ‘. . . is something like this’, and she showed the end result—a structure attempting to represent the whorled branches of a spruce tree. *VbS*, 28:58–30:12

The snippets above show that both Bessie and Rita had ideas for making fabric branches. The visual impressions (series of V-shapes) were similar; however, small changes in Bessie’s hand and finger positions—from shaping to pointing and gripping—completely changed the meanings related to the movements. Bessie and Rita developed the idea of tucking

and layering both visually and kinaesthetically. Neither described the process by speech. The details (whorled branches) were also omitted from the sketch but included in the 3D mock-up and the sewn spruce (Figure 10).

<Figure 10 left> <Figure 10 middle> <Figure 10 right>

**Figure 10** Three versions of a spruce: an outlined sketch, a more detailed 3D clay mock-up and the final version sewn from different coloured fabrics cut with pinking shears

While the above snippets are gesture-oriented, Authors (2016a) includes a sketch-oriented snippet, which captures the team fitting the forms together (operation 1).

#### 4. Discussion

While sketching is a well-established tool in designing, gestures are often considered typical non-verbal communication to some but not all. However, gestures have recently been considered as tools for reflective simulation (Cash and Maier, 2016) and kinaesthetic thinking (Eris et al., 2014; Streeck, 2008, 2009) as well as invoking new ideas (Goldin-Meadow, 2014). To expand the idea of gesturing as a creative collaborative tool and to understand how designers, especially novices, could benefit from gesturing, we investigated the roles of sketching and gesturing in the early collaborative ideation.

Regarding limitations, this detailed micro-level study focused on one team that exceptionally exhibited the phenomena of using rich and fluent gestures as well as engaged in collaborative sketching. The micro-level analysis in Authors (2016) showed that this team was the only one to maintain a shared object of attention throughout the design conversation; they engaged in effective collaboration and constantly shared both minuscule and sizable ideas for others to immediately build on and evaluate. *This selection of data suggests that generativity is not only about the tools but also the way the tools are used—how creative collaboration is organised both by and around the tools.* Another limitation was the use

of novices who lack practical (pure) design experience. However, the team members shared years of experience in sewing and handling textile materials—an experiential background against which to ‘generate’ and interpret gestures, that is, a base of embodied knowledge and kinaesthetic thinking for gestural conceptualisations (Streeck, 2009).

Our detailed video analysis confirmed the general level findings by Tang (1991), Visser (2009) and Eris et al. (2014), which showed that designers’ gestures convey meanings not communicated through other modalities. Three quarters of those complementary meanings contributed directly to designing and one quarter was classified as meta-communicative. Whether those complementary meanings invoked any ideas that otherwise would not have emerged, is of course impossible to prove. *The fact remains that several hundred ‘additional’ meanings—cues that prompt further ideas—were fed into the design process by gestures.* Harvesting that potential is a topic for future research.

Sketching and gesturing comparisons showed that sketching was powerful for designing structures, especially the complicated base-structure; however, structures were frequently introduced by gestures. For other design aspects, gestures were dominant. Our team was quite ‘skilled’ in gesturing. Interestingly, our results only partly support the finding by Eris et al. (2014), which found that sketching is used for detailing concepts. Otherwise, the current research confirmed many previous findings, which were reported in the introduction. Gestures offered the team a natural way to communicate both spatial and haptic meanings as well as prior embodied experiences on materials and making—their embodied haptic and kinaesthetic knowledge. Gedenryd (1998) saw every design move as having two purposes: to apply the knowledge and to (implicitly) test whether the knowledge is suitable. When gesturing an idea, team members evaluated the idea not only visually but also via proprioceptive feedback (Roth, 2000; Streeck, 2008), which especially benefited ideas iterated through a series of gestures, such as making spruce branches. Gesturing organised the world differently than what could have been done through words (Streeck, 2009). In trying to comprehend how visually impaired people imagine, perceive and identify objects in the material world, the students created gestural conceptualisations that utilised the hand-able dimension (Streeck, 2009). Those gestural conceptualisations became shared knowledge and were repeatedly used during the conversation, as were some other descriptive gestures. In



addition, certain gestures became part of the team's 'conceptual lexicon'.

Gesturers attempt to convey meanings but also to enable understanding in listeners (Enfield, 2009). Gesturing appears to be a highly situational practice that is influenced by participants' personal as well shared knowledge bases and personal styles. Hostetter (2011) not only lists message complexity and content but also gender, personality and learning style as possible factors that influence gesturing. Hummels (2000) emphasises individual differences as well and suggests diversity in tools. Our intention is to provide students with a toolset that actively supports early sharing of ideas and leveraging of collaborative ideation to gather inspiration from each other's creative ideas and thoughts. The current research guided us to understand that *the practice of sharing ideas as they emerge might benefit novices as much as any single design tool*. Subsequently, the main contributions are the micro-level video analysis method that focused on preserving kinesic and graphical characters of the studied phenomena, and the identification of three (families of) factors that influence both if and how gestures are used for designing:

- (1) how collaboration is organised (the level and immediacy of sharing);
- (2) characters of the design situation (e.g. level of pre-structuring of the work, environmental props and customer involvement) and
- (3) designers' personal preferences and skills.

We suggest that further research should identify design situations that include rich and versatile gestures and explore the factors mentioned above. Our provisional conclusion is that the abovementioned factors influence the use of design tools in general. To date, among studies that compare design tools, the first factor has not been sufficiently analysed as a contributing factor. In conclusion, the strength of gestures as collaborative creative design tools is that gestures guide us towards communicating rather than withdrawing.

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## Figures

Figure 1



Figure 2A

## 1 Design: Define Design Constraints

**Task 1:** List 10 questions on designing functional 3D puzzle for visually impaired children

**Task 2:** Make a mind map on design constraints

## 2 Design: Visualising by Sketching

**Individual creative problem solving**

1. Pick 4 numbers.
2. In 10 minutes, create an interesting, potentially useful object from the shapes (on the right) corresponding your first three numbers, and from the theme corresponding your fourth number. Do not change the shapes.

**Team work: Visualisation**

1. Share your work for the individual task.
2. Select a theme and shapes for your team puzzle. You may use and combine the shapes you picked for the individual task.
3. Sketch your 3D puzzle using the shapes.

Figure 2B



<b>3</b>	<b>Design: Build 3D Mock-up</b>
<p><b>Task:</b></p> <p>As a team, build up a 3D mock-up of your puzzle. Use the materials given to you by teachers.</p>	
<b>4</b>	<b>Make: Finalise your Puzzle</b>
<p><b>Task:</b></p> <p>Make your puzzle. Use textile materials.</p>	



Figure 3

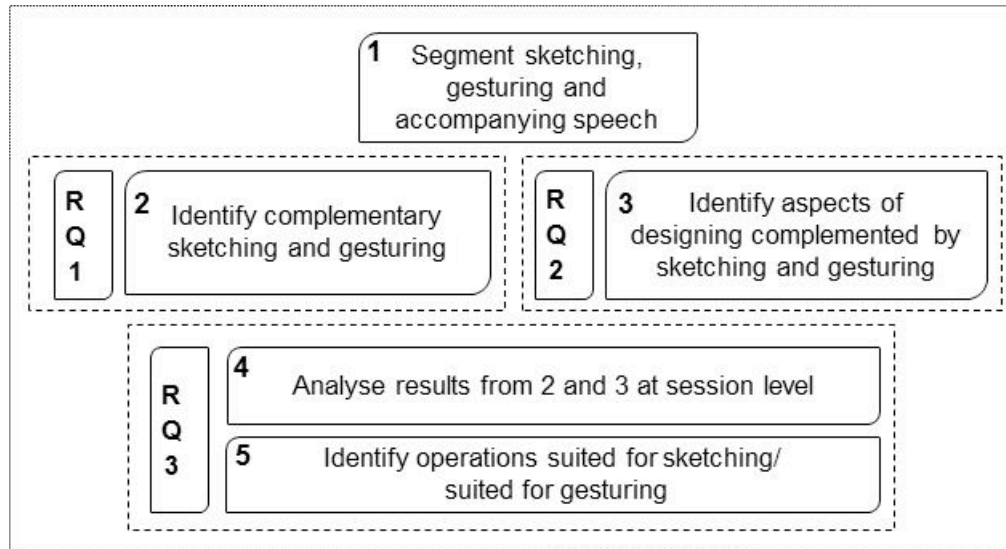


Figure 4

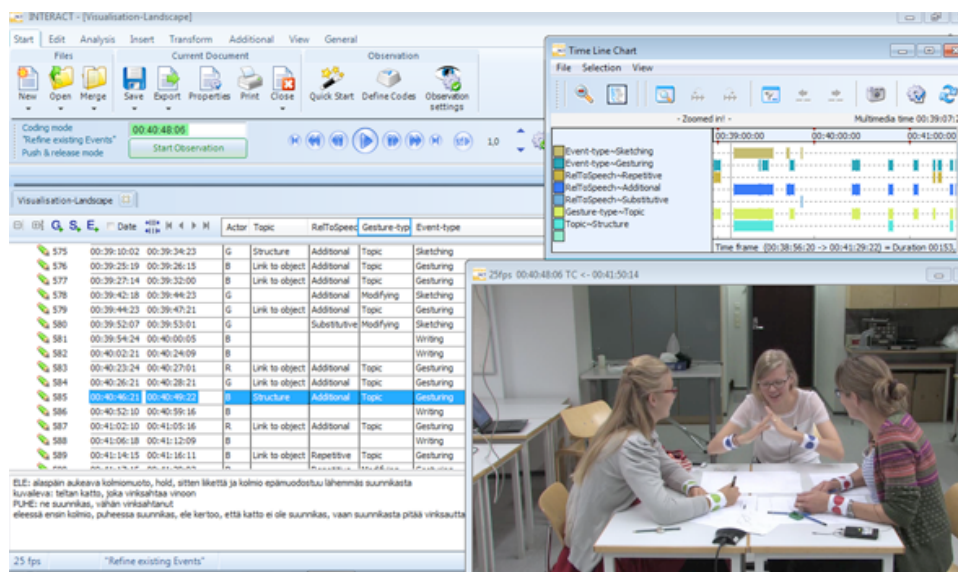


Figure 5



Figure 6



Figure 7



Figure 8 left

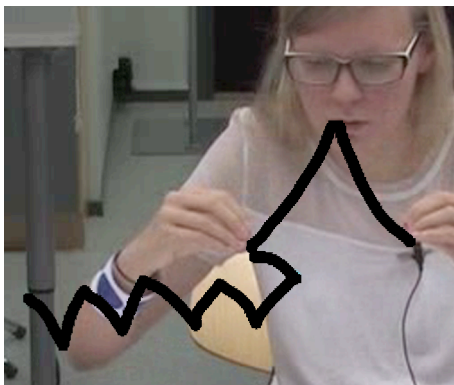


Figure 8 right

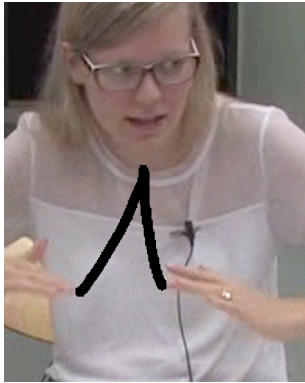


Figure 9 left



Figure 9 right



Figure 10 left

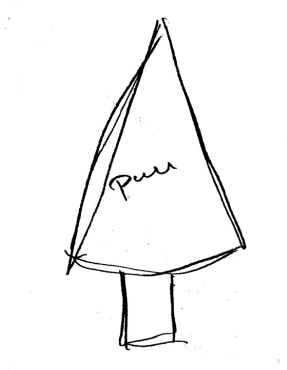


Figure 10 middle



Figure 10 right

